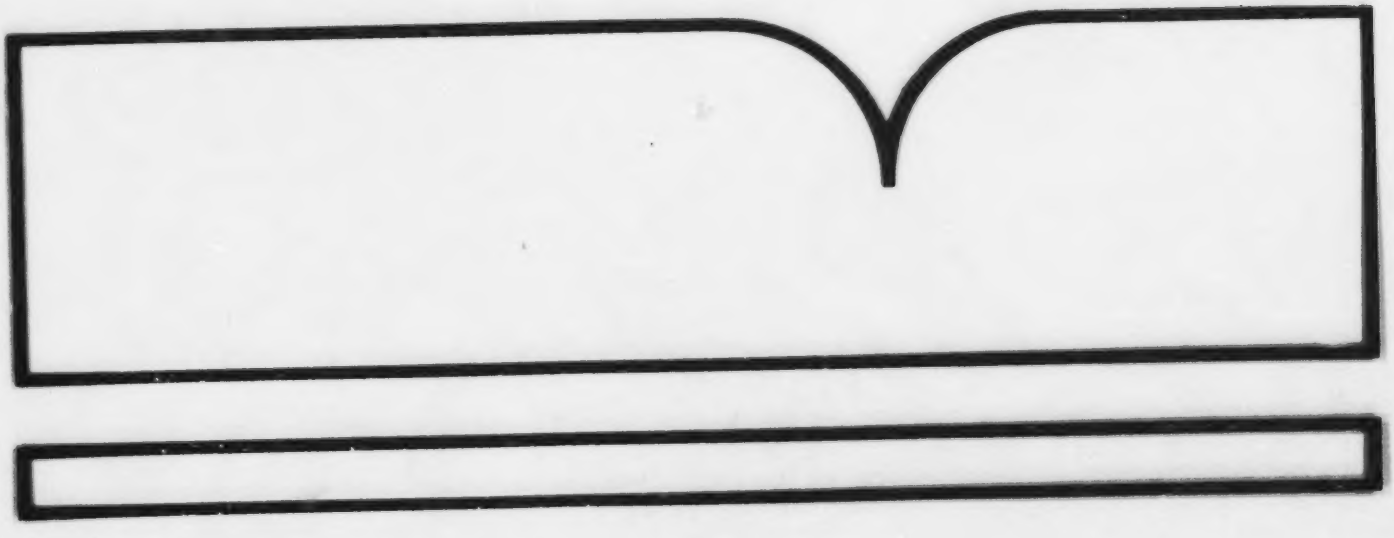
PB83-206961

Hazardous Waste Landfill Research

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

May 83



U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-206961

EPA-600/D-83-045
May 1983

HAZARDOUS WASTE LANDFILL RESEARCH

U.S.E.P.A. PROGRAM

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TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/D-83-045	2.	3. RECIPIENT'S ACCESSION NO. PB83 206961
4. TITLE AND SUBTITLE HAZARDOUS WASTE LANDFILL RESEARCH		5. REPORT DATE May 1983
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Norbert B. Schomaker		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS USEPA/MERL/SHWRD 26 West St. Clair Street Cincinnati, OH 45268		10. PROGRAM ELEMENT NO. BRD1A
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory--Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Symposium Paper
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES Norbert B. Schomaker 513/684-7871
Proceedings: ASTM International Symposium on Industrial and Hazardous Waste March 7-10, 1983 Philadelphia, PA

16. ABSTRACT

The hazardous waste land disposal research program is collecting data necessary to support implementation of disposal guidelines mandated by the "Resource Conservation and Recovery Act of 1976" (RCRA) PL 94-580. This program relating to the categorical areas of landfills, surface impoundments, and underground mines encompasses state-of-the-art documents, laboratory analysis, economic assessment, bench and pilot studies, and full scale field verification studies. Over the next five years the research will be reported as Technical Resource Documents in support of the Permit Writers Guidance Manuals. These manuals will be used to provide guidance for conducting the review and evaluation of land disposal permit applications. This paper will present an overview of this program and will report the current status of work in the various categorical areas.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 28
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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The hazardous waste land disposal research program is collecting data necessary to support implementation of disposal guidelines mandated by the "Resource Conservation and Recovery Act of 1976" (RCRA) PL 94-580. This program relating to the categorical areas of landfills, surface impoundments, and underground mines encompasses state-of-the-art documents, laboratory analysis, economic assessment, bench and pilot studies, and full scale field verification studies. Over the next five years the research will be reported as Technical Resource Documents (TRD) in support of the Permit Writers Guidance Manuals. These manuals will be used to provide guidance for conducting the review and evaluation of land disposal permit applications. This paper will present an overview of this program and will report the current status of work in the various categorical areas.

KEY WORDS

hazardous wastes, pollution, environmental surveys, waste disposal, earthfills, environmental engineering, environmental surveys, environmental tests, waste treatment, decontamination, containment, hydrogeology, leaching, linings

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This paper presents an overview of the hazardous waste land disposal research program as conducted by U.S.E.P.A.

BACKGROUND

Congress, through the Solid Waste Disposal Act (also known as the Resource Conservation and Recovery Act (RCRA), PL 94-580), directed the Environmental Protection Agency to develop programs for the management of hazardous and non-hazardous solid wastes. To effect the degree of coordination required of such an endeavor, a committee was formed to prepare and update an Agency wide research strategy. The Solid and Hazardous Waste Research Committee coordinates the efforts of the Office of Research and Development (ORD) with

those of the Office of Solid Waste (OSW), the Office of Waste Programs Enforcement (OWPE), the Office of Water Programs Operations (OWPO), the Office of Emergency and Remedial Response (OERR), and the EPA Regional Offices.

The Fiscal Year (FY) 1980 Solid and Hazardous Waste Research Strategy was based on the anticipated needs of the Agency as it implemented the mandates of RCRA. The major emphasis was placed on hazardous waste with continuing efforts in the municipal solid waste area. The FY 1981-1983 strategies focused entirely on hazardous wastes.

Agency responsibilities under RCRA are reasonably specific and future activities to fulfill those responsibilities have been scheduled according to a step-by-step strategy. Within this hazardous waste strategy, four research categories, which are described in the following sections, have been established. The four categories are:

- o Hazardous Waste Identification
- o Hazardous Waste Environmental Engineering Technology
- o Hazardous Waste Risk Assessment
- o Energy and Mineral Wastes

The Land Disposal Research program is identified with the Hazardous Waste Environemntal Engineering Technology category.

Hazardous Waste Identification

Hazardous waste identification includes sampling, analysis, characterization, measurement, monitoring, and quality assurance of measurements. The development of valid identification protocols is vital to the separation of hazardous from non-hazardous wastes and to the subsequent "cradle-to-grave" management of hazardous wastes. At present, our knowledge of many of the factors in the effective management of hazardous wastes is far from complete.

The strategy for hazardous waste identification is based on the need to provide a complete capability for the sampling and analysis of wastes which are potentially hazardous. Initial efforts are developing engineering and chemical screening methods and protocols. Multimedia monitoring methods are equally important and occupy a high priority in this area. Quality assurance for the monitoring program, necessary to ensure the validity of all of the data to be collected for characterization and subsequent monitoring of hazardous waste sources, are addressed.

Hazardous Waste Environmental Engineering Technology

With the environmentally unsafe options for management of hazardous waste eliminated by RCRA, generators must turn to the use of properly designed and constructed landfills or other alternatives. Improved treatment and disposal technology is necessary if hazardous materials are to be managed in a manner that is economically as well as environmentally sound.

The thorough study of all hazardous waste streams and potential treatment and disposal technologies is not feasible because of the variety of wastes considered hazardous; and funds would not likely be available to conduct such a mammoth undertaking. Immediate short-term efforts are focusing on those areas where the need is acute and industry research cannot be expected to be sufficient to meet needs. The land disposal strategy is presented in greater detail in following sections of this paper.

EPA's treatment research strategy is directed in three basic areas: preprocessing or predisposal treatment, thermal destruction and detoxification treatment. Short-term research efforts will concentrate on the refinement of existing technology for each of the three areas. Investigations of advanced technology are being addressed in the area of thermal destruction.

Hazardous Waste Risk Assessment

The paramount objective of EPA in the management of solid and hazardous wastes is the protection of public health from the effects of these substances by direct contact or transmission through the environment. In order to accomplish this objective, it is essential that reliable tools be available to enable EPA to gauge the potential impacts of various substances under various circumstances.

The research strategy for risk assessment includes the production of risk assessment documents for specific chemicals (scientific assessment), determination of toxic effects on humans likely to result from exposure to

hazardous wastes, development of methods and data to define environmental transport and fate characteristics of hazardous wastes, determination of likely ecological effects of environmental insult from hazardous wastes, and development of socioeconomic criteria and model scenarios of the impacts to be expected for various waste management incidents or disposal methods.

Energy and Mineral Wastes

Certain industrial and mining operations yield large volumes of waste containing some hazardous constituents. These special wastes include uranium mining wastes; phosphate mining, milling, and processing wastes; certain other mining wastes; cement kiln dust; utility wastes (coal ash and flue gas desulfurization wastes); and gas and oil drilling muds and brines.

Specific efforts include studies of wastes from coal-fired electric generating plants, uranium mining, phosphate mining and beneficiation, and from selected ore mining industries. Lysimeter studies of oil shale leaching were also conducted.

LAND DISPOSAL

The above four categories of research are being pursued by various research groups within the USEPA. The hazardous waste land disposal research program is part of the hazardous waste environmental engineering technology

category. Since the focus of this paper is orientated primarily towards hazardous waste land disposal research, it is this area which will be specifically addressed in this paper.

The program, encompassing state-of-the-art documents, laboratory analysis, bench and pilot studies, and full-scale field verification studies is at various stages of implementation.

The objective of this program is to compile a more adequate data base of information so that current hazardous waste disposal technology to the land may be upgraded by (a) developing proper site selection, design and operational criteria for the establishment of new waste disposal sites, and (b) developing proper control technology for upgrading existing waste disposal sites. The procedures thus developed will consider and describe those specific functions required to eliminate the pollution potential from landfills, surface impoundments, and underground mines. Specific functions include the ability to predict or provide guidance for determining leachate quality and quantity, quick indicator tests for the selection of lining materials, quick indicator tests for chemical fixation performance and compatibility with various generic waste streams, a methodology for minimizing moisture infiltration, alternatives to conventional landfills and predictors of environmental/economic impacts.

Over the next 5 years the research will be reported as criteria and guidance documents for user communities. The land disposal research program

is currently developing and compiling a data base for use in the development of guidelines and standards for waste residual disposal to the land as mandated by the "Resource Conservation and Recovery Act of 1976" (RCRA). Permit Writer's Guidance Manuals, which provide guidance for conducting the review and evaluation of permit applications, are currently being prepared by the Office of Solid Waste in Washington, D.C. Technical Resource Documents (TRD) in support of the Guidance Manuals are also being prepared by the Office of Research and Development in specific areas to provide best engineering technologies and methods for evaluating the performance of the applicant's design. The information and guidance presented in these manuals will constitute a suggested approach for review and evaluation and should be useful references for design and operation.

The current hazardous waste land disposal research program has been divided into five general areas: (a) Landfill ; (b) Surface Impoundment; (c) Underground Mines: (d) Economic Assessment of Hazardous Waste Disposal Practices and Alternatives, and (e) Technical Resource Documents (TRD) and Guidance Manuals.

LANDFILL

The landfill program examines components and unit operations of a hazardous waste landfill and optimizes their performance. The goal is to control and/or be able to predict the movement of liquids and gases in and

around a landfill. The program develops basic information for each component and prepares reports of research and user manuals for permit writers, design engineers, and operators.

The components and unit operations of a landfill to be addressed in this research include:

- o Waste Leaching
- o Pollutant Movement
- o Pollutant Control
- o Pollutant Treatment
- o Waste Modification

Waste Leaching

The overall objective of this research activity is to provide techniques for leaching a waste sample to obtain leachate similar to that which will occur when the waste is landfilled. A leaching procedure is being developed for use in determining which pollutants will be of concern in movement of leachates out of the landfill and for evaluating leachate treatment schemes in order to better develop pollutant control technology. A Technical Resource Document (TRD) was completed in FY 1982 on a batch leaching procedure and a comparative study of batch and column leaching methods will be implemented in FY 1983. The initial product will focus on leachate from well defined mixtures or single waste streams.

Pollutant Movement

The objective of pollutant movement work is to develop techniques which can be used in the design and regulation of clay-lined disposal facilities. These techniques will be developed to achieve a minimized, predictable release to the environment.

Because the processes of pollutant retention by soils do not operate independently of one another, understanding the causes of pollutant movement/retention in a specific situation is difficult. Heterogeneity of soil characteristics and the usual lack of knowledge about the types and composition of the variety of wastes accepted at a general disposal facility are further complications. Consequently, it is not presently possible to use soil and waste characteristics to predict pollutant movement/retention in soils at most hazardous waste disposal facilities with sufficient precision and accuracy to include the action of the soil or earth material as a reliable part of the design for the facility. To enhance designs and predictive capabilities, future facilities over sensitive aquifers, if not prohibited, may be restricted to a single waste or limited wastes of known migration characteristics. The capacity of soils and earth materials below the facility liner to retard the movement of pollutants may be used in future designs, but most likely as a safety factor rather than as a part of the primary facility design. As a result, containment through use of impermeable membrane liners, facility location and leachate collection are currently considered more important in protection of public health and the environment.

Current research is intended to develop tools for designing soil liners that limit pollutant release to a predictable minimum. The application is primarily for mono-waste landfills, but the information is also useful in design of soil liners for surface impoundments and in predicting the amounts of pollutants that will pass below the zone of incorporation in land treatment cells. The work is proceeding in two parallel phases. In the first, methods for predicting movement of liquid (leachate) are being developed and improved and in the second, methods are being developed for predicting how well soil liners will remove pollutants from any leachate.

Work is in progress on empirical predictive techniques using samples of wastes and soils from the location of interest. This approach appears to be the most promising way to integrate the effect of waste and soil characteristics on pollutant retention processes. The precision and accuracy that will be achieved by this method remains to be determined.

In FY 1981, a Technical Resource Document (TRD) on "Landfill and Surface Impoundment Performance Evaluation" (SW-869) for use by permit writers was published for public comment. This TRD is for predicting how much leachate will be intercepted by a leachate collection system and how much leachate will seep through the soil liner into underlying soils. Following analysis of public comment, this TRD will be finalized in FY 1983. A related TRD on methods for measuring flow properties entitled "Soil Properties, Classification, and Hydraulic Conductivity Testing" will be issued for public

comment in FY 1983. Research will be continued through FY 1985 to test the procedures in these two TRDs against field experience from the permit program for RCRA Section 3004. They will be updated as necessary.

Two additional TRDs on using batch and soil column techniques to predict pollutant removal from leachates by soil liners will be issued for peer technical review in FY 1983. Following public comment, final publication is planned for FY 1984. Field verification of this information will be achieved by a large scale field project and by analysis of data collected under the hazardous waste permit program.

Pollutant Control

The overall objective of this research activity is to evaluate and assess technology that minimizes, contains, or eliminates pollutant release and leaching from waste disposed to the land. The studies are determining how various soils, flexible membranes and admixed materials may be utilized as liners to contain and prevent leachates from migrating from landfill sites.

Procedures for selecting, placing, and predicting the life of liners in landfills and surface impoundments have been the main thrust of research efforts prior to FY 1981. Information on these procedures is contained in the TRD "Lining of Waste Impoundments and Disposal Facilities" (SW-870). This TRD was revised and updated in FY 1982 based on public comments and additional research data. Final publication will be in FY 1983.

In FY 1982 a research program was initiated to evaluate and assess advanced liner designs, including emerging flexible membrane liners and the use of nonpetroleum-based materials (such as sulfur/hydrocarbon compounds) in place of asphalt. FY 1983 studies will evaluate the seaming techniques necessary to adequately seam a variety of flexible membrane liner materials under various environmental conditions, the quality control necessary to insure the integrity of the seams, and the beneficial aspects of placing soil or soil like material over membrane liners. Studies will continue to ascertain the proper placement procedures and the use of non-soil materials to assist in bedding requirements for synthetic membranes and leachate and gas collectors. Studies will be initiated to field validate non-destructive leak evaluation techniques of in-situ materials. Repairs of damaged/leaking membrane liners will be evaluated from a quick patch, retrofitting or complete replacement basis.

Another major effort in FY 1983 will be the identification of Federal agencies actively involved in liner technology research for the purpose of data interpretation on a national scale. This information will be utilized to standardize tests and materials for industry use.

The research program will continue laboratory and pilot scale operations and initiate field verification studies in early FY 1983. Laboratory studies will assess various approaches on predicting service life based on the chemistry of the liner and waste. Field conditions and their effects on liner materials will identify problems either as improper liner selection or

placement and mismanagement of liner systems. The field surveys will also identify why certain systems continue to perform as based upon original design concepts. As this data becomes available the TRD will be updated. It is also envisioned that additional TRD's could be generated on specific liner technology achievements.

Pollutant control research is also addressing the issue of minimizing moisture infiltration into the site by constructing adequate cover systems. Two TRDs were developed in FY 1980 for public comment. SW 867 "Evaluating Cover Systems for Solid and Hazardous Waste" provides procedures for evaluating/designing cover systems utilizing existing site materials, bringing in additional soil types not found at the site, or the use of synthetic membranes to act as moisture barriers. "Hydrologic Simulation on Solid Waste Disposal Sites" (SW 868) is an interactive computer model to determine the moisture infiltration through a cover system. In FY 1982 this model was revised for two-dimensional considerations and additional default values added. Both TRDs were revised in late FY 1982 and were published in final form in FY 1983. Copies of these two documents can be obtained from the Government Printing Office (GPO) in Washington, D.C. 20402. The GPO stock numbers are 055-000-00228-2 and 055-000-00225-8, respectively. As additional research information becomes available, the TRD will again be revised. Research initiated in FY 1982 includes a project addressing the Quality Control procedures which need to be applied to geotechnical parameters that are evaluated during land disposal site design and construction. In addition, a field-scale study designed to provide soil moisture data which would allow

verification of drainage models applied to landfill cover systems was begun. This project includes an approach to measuring the impact of subsidence imposed on a small section of the constructed cover system. The FY 1983 emphasis will be directed toward field verification studied for validation of concepts and techniques developed by the research program.

Pollutant Treatment

The objective of pollutant treatment work is to identify the composition of leachates being generated from hazardous waste landfills and to assess the application of treatment technology for neutralizing or detoxifying the collected leachate.

The use of a leachate collection and removal system to minimize the seepage of leachate into underlying soils is an integral part of the landfill concept for hazardous waste disposal. Consequently, research has been initiated characterizing procedures for collecting and treating leachate to insure that it is disposed of safely.

Leachate treatment schemes will likely include biological, physical, or chemical processes either singly or in combination depending on the characteristics of the leachate involved. Similarities will exist between the combination of processes selected for leachates from co-disposal and leachates from strictly municipal solid waste (MSW). The leachate characteristics from co-disposal facilities may be expected to be very similar to municipal refuse leachate. Consequently, completed studies of MSW should be useful in selecting appropriate treatment schemes.

In FY 1981 a TRD "Management of Hazardous Waste Leachate" (SW-871) was issued for public comment. Also, pilot scale treatment studies with several waste leachates and contaminated groundwaters were initiated.

During FY 1982 the TRD was revised to incorporate public comment and interim results from treatment projects and was published in final form in FY 1983. Copies can be obtained from the Government Printing Office (GPO). The GPO stock number is 055-000-00224-0. In FY 1983, further studies to develop physical, chemical, and biological approaches to treatment of leachates will be initiated. The research will focus on protocols for matching leachate quality with the appropriate combination of treatment processes. During this period additional field studies will be initiated to validate results obtained from bench and pilot scale studies. By FY 1985 the TRD will be updated to take into account results from the various research programs and experience with use of the TRD in the hazardous waste permit program.

Waste Modification

Chemical solidification/stabilization is achieved by incorporating the solid and liquid phases of a waste into a relatively inert matrix which exhibits increased physical strength and protects the components of the waste from dissolution by rainfall or by soil water. If this slows the rate of release of pollutants from the waste sufficiently and no serious stresses are exerted on the environment around the disposal site, then the wastes have been rendered essentially harmless and technical restrictions on siting will be minimal.

The objective of the waste modification work is to validate the performance of chemically solidified/stabilized wastes. This validation is addressing four basic goals:

(1) Improvement in handling and physical characteristics of waste materials.
(2) Decrease in the surface area across which transfer or loss of contained pollutants can occur.
(3) Reduce solubility of any pollutant contained in the waste.
(4) Detoxify contained pollutants.

One of the options being investigated is alteration of the waste to minimize or prevent release of pollutants from the wastes. Fixation converts the waste to a physically stronger and/or less soluble form while encapsulation incorporates the waste into a strong, low solubility matrix. Encapsulation, the more durable and expensive process, is designed for low-volume, high-toxicity wastes.

In FY 1981 a TRD entitled, "Guide to the Disposal of Chemically Stabilized and Solidified Waste" (SW-872) was published for public comment. Although it contains some information on encapsulation, it deals mainly with fixation processes and gives procedures for evaluating the suitability of combinations of inorganic wastes and fixation processes. The TRD was revised in late FY 1982 based on public comments and additional research data and was published in final form in 1983. Copies can be obtained from the Government Printing

Office (GPO). THE GPO stock number is 055-000-00226-6. A field survey of 7 to 10-year old sites containing chemically fixed inorganic wastes was undertaken to develop verification information for the TRD.

In FY 1983, information will be expanded on fixation processes for organic wastes and work initiated on development of procedures for evaluating fixation process suitability under long-term (100 years) worst-case scenarios. Studies of encapsulated waste products and production of state-of-the-art for encapsulation processes will be completed.

SURFACE IMPOUNDMENTS

The surface impoundment research program has been modified to provide a comprehensive understanding of the design, operation, and maintenance of surface impoundments as options for hazardous waste disposal. Information is needed on the use of natural soils as liners and the correlation of laboratory measurements with the construction standards achieveable in the field. Of particular interest is the degree to which specification of construction techniques and inspection practice can influence uniformity and performance of the finished impoundment.

Containment

The use of natural soils as liners is attractive because on-site availability can lower construction costs. However, waste-soil interactions can pose problems in addition to those normally involved in earthen structures. The potential contact of soluble/liquid organic compounds with soil is much greater in surface impoundments than in other disposal facilities. Any resulting changes in soil structure or permeability are serious because of the large area of liquid/surface interface contact and the effect of the hydraulic head. Work is underway on predicting the effects of organic wastes on soil properties. This will be continued and opportunities for field verification developed. The emphasis is on identifying effective techniques for determining the compatibility of a specific waste and soil rather than on collecting comprehensive data concerning a variety of wastes and soils.

Work on the passage of pollutants through soil liners is being conducted as part of the work on landfills; work on the effects of organic wastes on the durability and other properties of soil and flexible membrane lining materials is also included. The information developed will be applied to surface impoundments as well. Procedures for evaluating the effects of wastes on natural and flexible membrane lining materials and earthen structures that are unique to surface impoundment, for example wave action, aeration and mixing, sunlight, and solids settling on the liner in the impoundment will be evaluated.

Because of the large ratio of exposed surface area to volume in surface impoundments, the potential for emission of volatile organic compounds into the ambient air is of particular concern. A procedure for predicting air emissions as a function of waste composition, impoundment design, and weather conditions is being developed. A field monitoring program will verify the predictive method. A final phase in this work will be the development of a TRD addressing the use of the predictive model and the field verification procedure.

Another area of concern is the siting/size problem. The socioeconomic aspects of this problem will be addressed in tandem with similar research effects for landfills and land treatment facilities. A complicating constraint that must be addressed is the economic disincentive to locate a surface impoundment at any great distance from the source generating the waste. The size problem is independent of location and requires development of methods for assessing the tradeoff between increased potential for environmental damage (area seepage, dike failure) from larger impoundments and the economies of scale achievable as impoundment size is increased. Initial studies will examine the magnitude of these factors for a series of smaller impoundments containing the same total volume as a single large impoundment.

Closure of surface impoundments has been an initial concern because of the uncontrolled dump site problem. As such, a TRD "Closure of Hazardous Wate Surface Impoudments" (SW-873) was published in FY 1981 for public comment and review. It has been revised and published in FY 1983. Copies can be obtained

from the Government Printing Office (GPO). The GPO stock number is 055-000-00227-4.

Performance Evaluation

Additional Technical Resource Documents (TRD) are being developed for conducting performance evaluations of surface impoundment under different designs. The source of information and data will be generated from field surveys where the advantages and disadvantages of specific designs, management procedures, geographic location and waste contained are identified and evaluated. This data set is envisioned to produce information that can be modeled to predict the success or failure of future designs. This is expected to be available in early FY 1984.

UNDERGROUND MINES

The use of underground salt mines for the long-term controlled storage of nonradioactive hazardous wastes has been shown to be promising as a result of studies by EPA and others and by the successful commercial operation of such a facility in West Germany since 1973.

A research program on characterization and containment of hazardous wastes for mine disposal was completed in 1977. This effort included determination of suitable mine locations, determining waste handling requirements, specifying operational techniques, and the preliminary design of a mine

disposal system. This material was used to develop a feasibility report. Based upon the feasibility report, one or more candiate mines was selected for further evaluation and detailed economic design. An engineering plan for an initial pilot-scale operation was developed and a full-scale demonstration was planned in cooperation with a private firm, but never implemented. In FY 1983 an update of hazardous waste disposal into underground mines state-of-the-art will be initiated.

ECONOMIC ASSESSMENT

The objective of economic assessment work is to provide cost information and evaluation methods for land disposal and remedial action technologies.

Recently completed efforts include the development of a method to analyze the economic and social effects of alternative approaches to hazardous waste management, the determination of unit costs for sixteen treatment and five disposal techniques applicable to various hazardous waste streams, and the analysis of unit operations cost data for long term remedial action programs at uncontrolled hazardous waste sites. Ongoing efforts include the analysis of actual remedial action costs from case studies, the development of a standardized method for conducting cost-effectiveness analysis of remedial actions at uncontrolled sites, and the analysis of human safety and degree-of-hazard considerations on remedial action costs. Technology cost information is also being developed as part of many efforts involving land disposal and remedial action technology evaluation and development.

TECHNICAL RESOURCE DOCUMENTS

The Technical Resource Documents (TRDs) which have been mentioned in this paper consist of a series of documents which represent Best Engineering Judgement (BEJ) for the design, operation and closure of hazardous waste disposal facilities. These documents are a compilation of research efforts to date and are being developed to assist in the implementation of 40 Codified Federal Register, Parts 264, 265, and 267 regulations concerning hazardous waste disposal facilities (landfills, surface impoundments, and land treatment). These documents are technically oriented and not policy oriented. They are not regulatory by design, but are intended only to provide guidance in decision making processes for use as a guide by permit writers for evaluating facility designs and potential performance of new waste disposal facilities. The documents will be updated continuously as now information is developed. Some of the manuals provide specific design and operational information (i.e. closure and lining TRD) while others are intended as evaluation tools (i.e. hydrologic simulation and performance evaluation). Eight TRDs have been completed to date. Six of these documents are related to landfills and one document each is related to surface impoundments and land treatment. Research on land treatment of hazardous wastes has been transferred to the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma. However, the initial version of the "Land Treatment" TRD is being published by the Solid and Hazardous Waste Research Division and is therefore included in this report. A brief description of each TRD document is listed below:

TRD 1, Evaluating Cover Systems for Solid and Hazardous Waste (SW-867): This document presents a procedure for evaluating cover systems for solid and hazardous waste landfills. It contains a checklist, with supporting documentation, that a permit writer can use to evaluate a proposed cover system.

TRD 2, Hydrologic Simulation on Solid Waste Disposal Sites (SW-868): This document provides a computer package to aid planners and designers by simulating hydrologic characteristics of landfill covers to predict percolation as a function or cover design and climate.

TRD 3, Landfill and Surface Impoundment Performance Evaluation (SW-869): This document describes how to evaluate leachate collection systems using compacted clay or flexible membrane liners to determine how much leachate will be collected and how much will seep through the liner into underlying soils. The adequacy of sand and gravel drain layers, slope, and pipe spacing are also covered.

TRD 4, Lining of Waste Impoundment and Disposal Facilities (SW-870): This document provides information and guidance on liner systems. It discusses waste, liner types, compatibility, liner selection, specifications, design of leachate collection systems, and case study analysis methodology. It also includes a glossary of liner system related terms.

TRD 5, Management of Hazardous Waste Leachate (SW-871): This document discusses leachate composition, leachate generation, selected management options, available treatment technologies, unit-treatment options, and system economics. It presents management options that a permit writer or hazardous waste landfill operator may consider in controlling and treating leachate.

TRD 6, Guide to the Disposal of Chemically Stabilized and Solidified Wastes (SW-872): This document provides basic information on stabilization/solidification of industrial wastes; examines the regulatory considerations, current and other options involved in disposal systems using stabilization/ solidification of wastes. A summary of the major physical and chemical properties of treated wastes is presented. A listing of major suppliers of stabilization/solidification technology and a summary of each process is included.

TRD 7, Closure of Hazardous Waste Surface Impoundments (SW-873): This document discusses and references the methods, tests, and procedures involved in closing a surface impoundment in a manner that (a) minimizes the need for further maintenance, and (b) controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous waste composition, leachate, contaminated rainfall, waste decomposition products to groundwater, surface waters, or the atmosphere. Problems that have been overlooked in abandoned impoundments and have caused environmental degradation are discussed. The document discusses

closing an impoundment either by removing the hazardous wastes or by consolidating the waste onsite and securing the site as a landfill. Relevant literature or specific procedures are documented to provide greater detail.

TRD 8, Hazardous Waste Land Treatment (SW-874): This document discusses the land treatment disposal concept, characteristics of hazardous waste, allowable waste loadings, facility planning for land treatment, land treatment permit process, closure, and items to be considerered during permit evaluation.

CONCLUSIONS

This paper represents an overview of the hazardous waste land disposal research program conducted by the USEPA. Specific areas discussed in order of priority were landfills, surface impoundments, and underground mines. All activities in these areas are being summarized into Technical Resource Documents to provide guidance in regulatory decision making processes. These documents will be regularly updated to reflect the latest research findings; the documents will eventually be condensed into guidance manuals. A guidance manual will be prepared for landfills and surface impoundments. More information about specific aspects of the hazardous waste land disposal research program can be obtained by contacting the author.